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Human Effectiveness DIRECTORATE

ANIMAL NOISE MONITOR: ASSESSMENT OF ACCELEROMETERS FOR DETERMINING ANIMAL BEHAVIOR

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March 2000

Interim Report for the Period October 1998 to March 2000

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NOTICES

TECHNICAL REVIEW AND APPROVAL

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The experiments reported herein were conducted according to the "Guide for the Care and Use of Laboratory Animals," Institute of Laboratory Animal Resources, National Research Council.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

//Signed//

MARIS M. VIKMANIS
Chief, Warfighter Interface Division
Air Force Research Laboratory

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The Environmental Impact Analysis Process (EIAP) requires that the Department of Defense be able to assess the impacts of noise on animals. The National Park Service and Fish and Wildlife Service, who have oversight on DoD environmental documents, have expressed concern about noise impacts on wildlife from military overflights. The USAF undertook an effort to develop an animal noise monitor that would measure directly the noise impact and determine the activity condition of the animal. This effort was to examine the use of accelerometers for determining the activity level of wildlife, especially Bighorn sheep, mule deer and prong horned antelope. This effort was able to show the correlation of accelerometer data with observed behavior from wildlife experts. Three approaches for implementing accelerometers into an overall system design are proposed.

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PREFACE

This project was conducted by the Air Force Research Laboratory's Human Effectiveness Directorate. This project manager was Dr. Micah Downing and the work was completed under Workunit 71841603 "Environmental Noise Research". The author would like to acknowledge the technical assistance of Dr Paul Krausman, University of Arizona, for his contribution of wildlife behavior and the basic data collection that was recorded on white tailed deer.

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BACKGROUND

The Animal Noise Monitor (ANM) project's goal is to study the potential effects of aircraft flyovers on free ranging big horn sheep. Part of this goal is to monitor the animal's activity level by use of an accelerometer. The ANM is designed to operate while being worn by a big horn sheep for a period of 6 to 9 months. During this time the ANM will collect hourly noise levels, Leq, as well as sound exposure levels, SEL's, from single noise events, activity levels, and daily location. The SEL will be collected for noise levels that exceed a predetermined threshold for a set duration. A GPS unit obtained the daily position of the animal. The unit will automatically disengage at the end of the study without having to recapture the animal. It is also the goal of the study to have biologist observe remotely the collared sheep. The outcome from this observational study will help to determine if aircraft noise influence the sheep in any way that may be detrimental to their survival.

This report summarizes the results from the accelerometer feasibility test for the Animal Noise Monitor (ANM). The test was performed to check the feasibility of using acceleration to quantify the activity of a collared animal. This activity measure would then be used to determine any influence that aircraft flyover noise may have on the animal. The determination was done by correlating the acceleration data with the measured noise data. This feature will greatly enhance the data collected by the ANM. This report includes a brief description of the feasibility test, a discussion of the data analysis, and recommendation of three approaches for consideration along with their impact on the system design.

METHOD

FEASIBILITY TEST

A mule deer was fitted with an accelerometer and Digital Audio Tape (DAT) recorder attached by a collar. The size and weight of this test collar was approximately the same as the designed ANM. Also, the accelerometer was located similar to its designed placement in the ANM. While the deer was collared, a video was recorded showing the movement of the deer and a biologist recorded observation of its activity state. The video, activity, and observation data were time synched to facilitate analysis. Video and acceleration data were collected for 90 minutes from 0630 to 0800 on 24 June 1998 (reference Krausman 1 July letter). The data collection was started when four personnel released the deer. It should be noted that a calibrated signal was not recorded for the accelerometer, so all reported levels can only be compared relatively to one another and cannot be translated into any physical units.

The deer was inside a fenced area that restricted its range. The deer had a pattern of walking from side to side in the pen and was restrained from a free run because of the limited space. Therefore, the restricted motion could influence some of the observations. This constraint needs to be remembered when extrapolation is made to the free ranging condition.

ANALYSIS

The video, the accelerometer recording, and the biologist's observations were delivered to the Bioacoustics Branch of the Air Force Research Laboratory for analysis. A strip chart of the accelerometer data was generated to facilitate interpretation of the data. The data were charted in actual Root-Mean Square (RMS) levels. The initial observations from the video and the strip chart were that the biologist's observation did not correspond accurately to the acceleration data and that headshakes produced high peak acceleration levels. Headshake levels were much larger than trotting levels but had a shorter duration. Also, it should be noted that the deer was upright for most the time with very few moments of rest during the data collection. From this strip chart seven one-minute segments were selected for detailed analysis. These segments are the following and noted by the time relative to the start of data collection:

A	2:25 - 3:25	Walking and Trotting
B	4:19 - 5:19	Walking and Head Shake
C	5:19 - 6:19	Head Shake
D	7:17 - 8:17	Head Shake and standing
E	8:30 - 9:30	Head Shake and standing
F	19:15- 20:15	Voiding and grooming
G	82:15 - 83:15	Jumping, running, and frantic (Prof. Krausman entered pen)

Detailed analysis involved three separate approaches: spectral time histories, velocity calculation to approximate the kinetic energy, and maximum accelerations. The first approach obtained the spectral time histories for the above segments and developed an energy metric similar to acoustic analysis. This approach was tested to discern the effect of headshakes by

integrating the energy over a longer time period. The data were analyzed over a frequency range of 1.3 to 4,000 Hz. From the spectral time histories, the unweighted overall level was calculated with an arbitrary reference level since no calibration signal was provided. The time histories of the overall level provide a good representation of the motion. These plots are provided in Appendix A. However, in comparing the different segments the levels gave conflicting answers. The levels for Segment G, in which the deer was frantic, were lower than the other segments except for F, in which the deer was voiding and grooming. This result was not correct because the deer's actual activity increased dramatically in segment G. There does not appear to be reason for this apparent discrepancy.

Figure A-8 plots the spectra from various portions of Segment B as noted below:

11.25	peak spectrum of a trot
33.5	middle of a trot/walk
41.0	standing
44.25	peak spectrum of headshake
55.0	minimum spectrum of segment.

This figure shows that the primary energy ranged from 3 to 65 Hz with a peak around 5 Hz for all portions except for the head shakes. Head shakes generated higher energy levels from 6 to 100 Hz with peaks occurring at 8 and 20 Hz, but the spectral shapes are basically the same. These spectra were representative for all of the data. Figure A-9 shows the spectra for a portion of Segment G as noted below:

10.0	running
23.625	running
37.5	running into fence
46.75	jumping into fence.

The first two spectra are similar to the spectra in figure A-8. The last two spectra correspond to the two highest peaks in the strip chart but are probably corrupted by the deer hitting the fence.

The second approach was to integrate the acceleration data to get velocity. Velocity could then be used to estimate the energy level since the square of velocity is directly proportional to kinetic energy. The velocity plots (Appendix B) provide a good time history representation of the deer's motion.

The third approach resulted from the observation that during the velocity calculation that the RMS acceleration provided a good time history as well. This approach involved collecting the maximum value of RMS acceleration for a set time interval. Plots of the maximum acceleration plots are provided in Appendix C. These plots show the results from using 1-, 2- and 5-second intervals for the maximum acceleration. The 5-second interval missed low acceleration periods, as when the deer was turning around, but this may not be important since that was a direct result of the pen. The 2-second interval represented the penned deer's motion accurately. It was fine enough to capture the spikes from headshakes and the low motion states when the deer turned around in the pen. The 1-second interval did not seem to add any more information than the 2-second interval. Also, in Appendix C, a summary table of the binning

scheme is provided that shows that relative time for each state using slightly different criteria. From the feasibility test the 2-second period seemed to be the optimal choice. However, if this approach is used, then the selection of the duration of the hold period should consider that the animal would be free ranging.

CONCLUSIONS

SUMMARY OF ACCELERATION DATA

The first observation from this test was that headshakes produced large acceleration levels primarily because of the location of the accelerometer around the neck of the deer. The relative importance of headshakes needs to be discussed with a biologist in order to determine if headshakes are important when compared to whole body motion. If headshakes are important or not, the maximum acceleration collection approach should allow post processing to identify headshakes. From this analysis, the second observation follows that a 2-second maximum acceleration collection scheme provides enough resolution to measure the motion of the deer including headshakes. Calculation of the maximum RMS acceleration of the raw signal is the easiest approach to implement electronically and requires fewer computational steps to obtain a number. This approach when combined with the idea of binning the levels into four groups is an efficient fit for the ANM. This binning approach mimics the observational parameters used by the biologist. Binning level data will reduce memory requirements while maintaining meaningful data. However, care must be taken in identifying activity states with the bins. The use of the first and second approaches are not justified when the end result will be a two bit number and especially since these other two approaches do not better discern headshakes. It should be noted that these summary observations are based on the activity of a penned deer.

DESIGN IMPACT

Option 1. To monitor the activity level of an animal the accelerometer needs to be on 100% of the time to avoid complicated analysis and to eliminate risk of incorrect conclusions. A 2- or 5-second maximum RMS acceleration data with levels binned into 4 groups should be sufficient to describe the activity of the animal. Calibration test will be required on each animal type to determine the appropriate binning levels. With this approach the activity levels can easily be compared to the noise levels to determine any influence. One drawback to this approach is the data memory requirements. With the activity data collection on all of the time, using a 2-second interval, 11 KB of acceleration data would be generated each day (1 byte every 8 seconds), and using a 5-second, 4 KB would be generated (1 byte every 20 seconds). But, as you extend the time interval from two to five seconds, then random headshakes may generate a false representation of an extended period of high activity.

This option requires the accelerometer to be on all of the time (similar power consumption of the microphone) and generates a lot of data. Current memory of the ANM is approximately 80 KB, thus the unit would have to be downloaded every week for a 2 second interval or 2.5 weeks for a 5 second interval just for the acceleration data. However, the ANM power management has been designed for data downloading to occur every three to four weeks.

Therefore, this scheme has feasibility but would reduce the field life because the data transmission power requirements would limit the ANM to a maximum field time of three months using the 2 second interval and 7 months using a 5 second interval.

Option 2. If activity data cannot be collected 100% of the time, the field life could be extended by selective use of the acceleration function. This function could be turned on and off by use of the ANM's two-way communication. Using this approach, acceleration data would not be collected during some portions of the testing period. These periods should be selected by consultation between the biologist and the air space managers.

Option 3. Status quo. The current design approach for the acceleration data with the ANM is to record a sample every hour and for 30 seconds after a noise event. Otherwise the accelerometer is off. This approach would be to keep the status quo. This means the animal's activity would be sampled (2 second sample every hour) and recorded for 30 seconds after a noise threshold crossing. This approach would collect data that requires statistical analysis with the following hypothesis to be tested: Does the activity of the animal change after a noise exposure? This approach assumes that the activity is random. I believe this assumption is not valid for wild animals. Thus, the statistical analysis will have to include the natural variation in the animal's activity throughout the whole day. This would have to be done on animals that are not over flown so that the influence of the over flights is not confounded with natural activity. Moreover, this approach does not allow you to determine the relative change in an animal's activity state in response to an aircraft flyover. Therefore, this option should not be used by the ANM for assessing the activity levels.

RECOMMENDATIONS

The concept of using an accelerometer to measure an animal's activity is feasible. I recommend that option 2 be incorporated into the ANM data collection scheme. This option allows for detailed activity data to be collected and examined while maintaining the desired field life of the unit. From the test case, the 2-second interval is the optimal choice, since it easily discerned headshakes.

Appendix A: Acceleration level time histories (3rd octave band) and comparison spectra

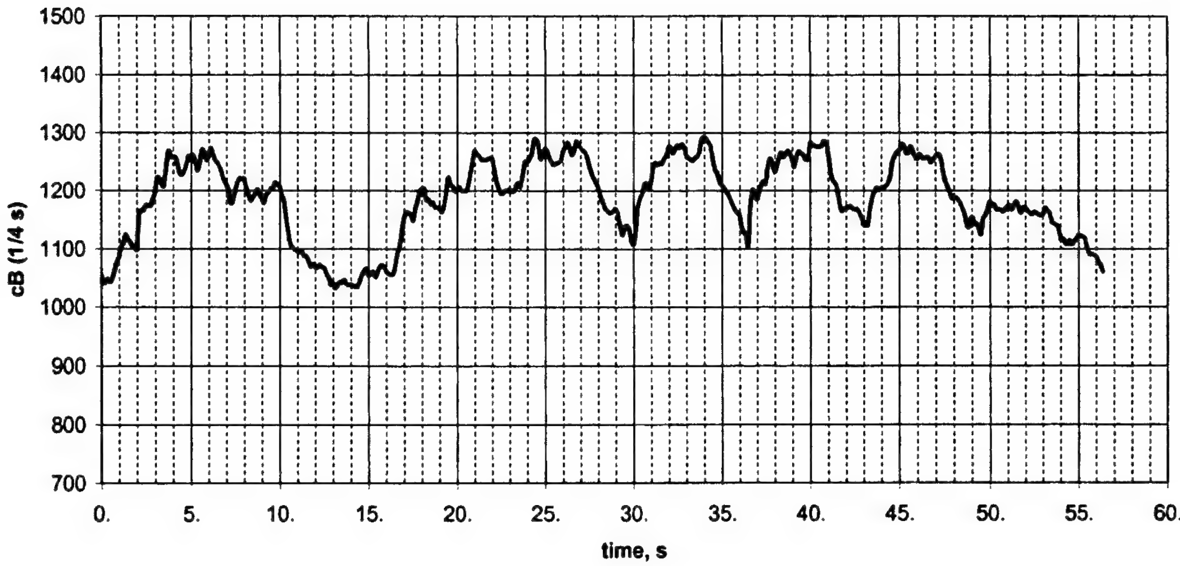

Figure A-1. Spectral Energy: Segment A (2:20 – 3:20)

Walking and Trotting

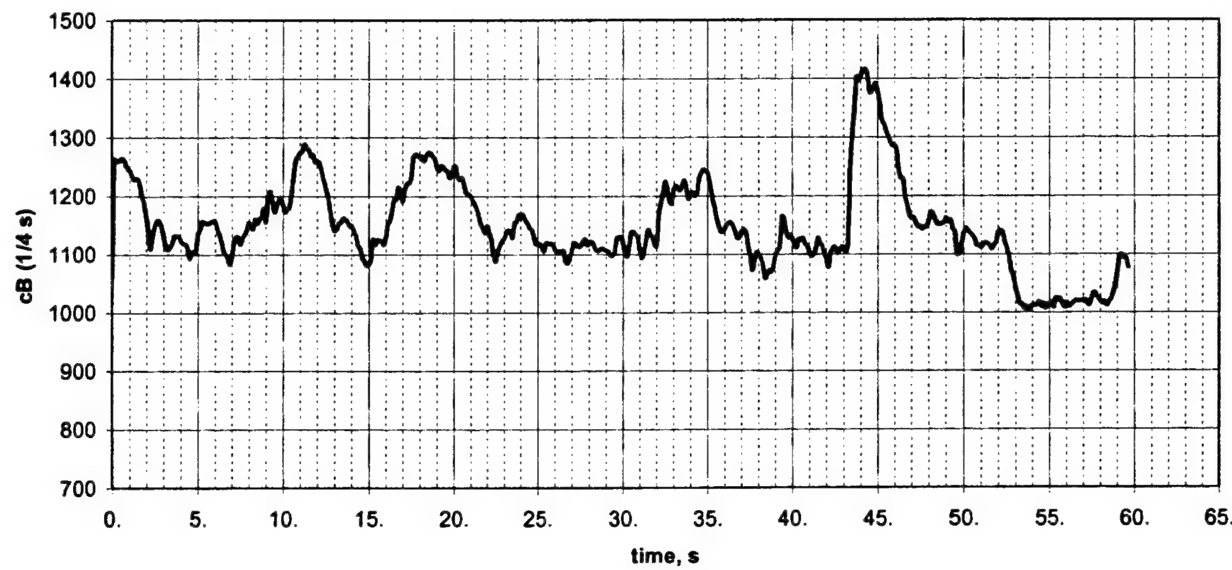

Figure A-2. Spectral Energy: segment B (4:15- 5:15)

Walking and Headshake

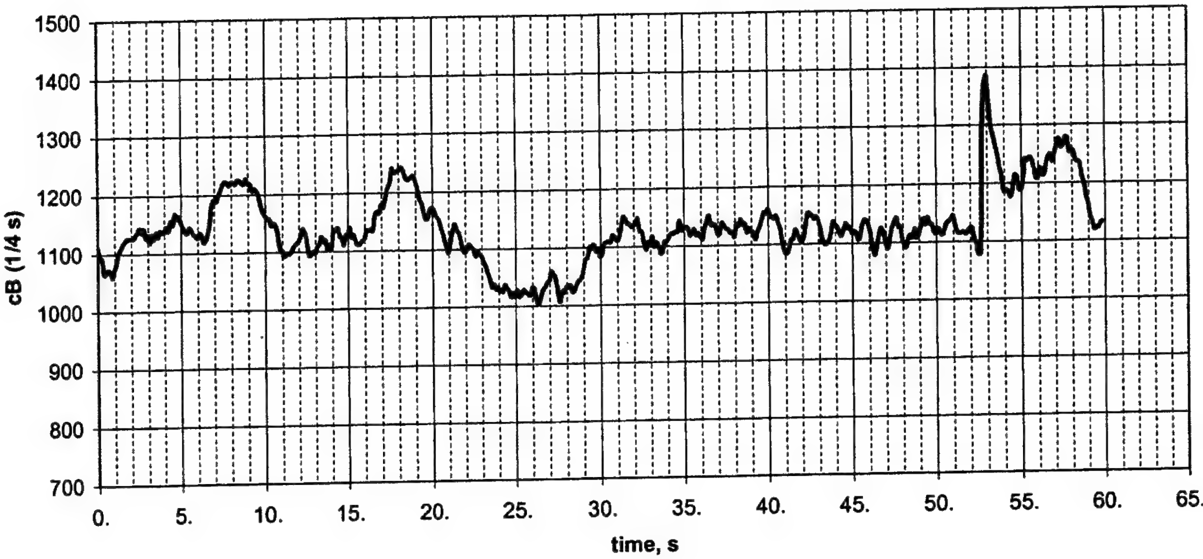

Figure A-3. Spectral Energy: Segment C (5:20 – 6:20)

Headshake

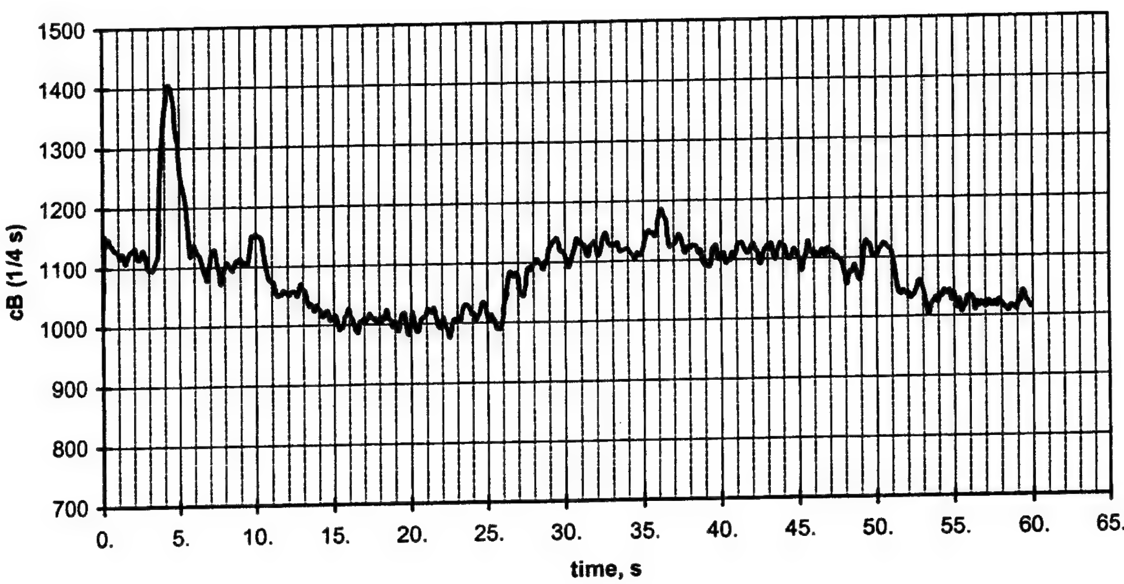

Figure A-4. Spectral Energy: Segment D (7:15 – 8:15)

Headshake and Standing

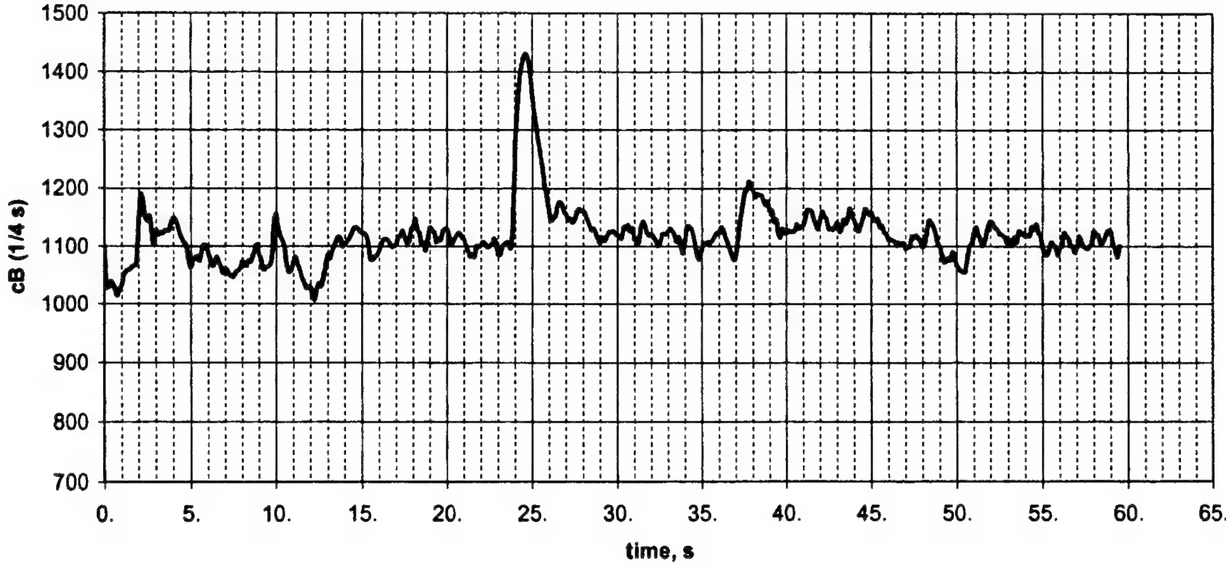

Figure A-5. Spectral Energy: Segment E (8:15 – 9:15)

Headshake and Standing

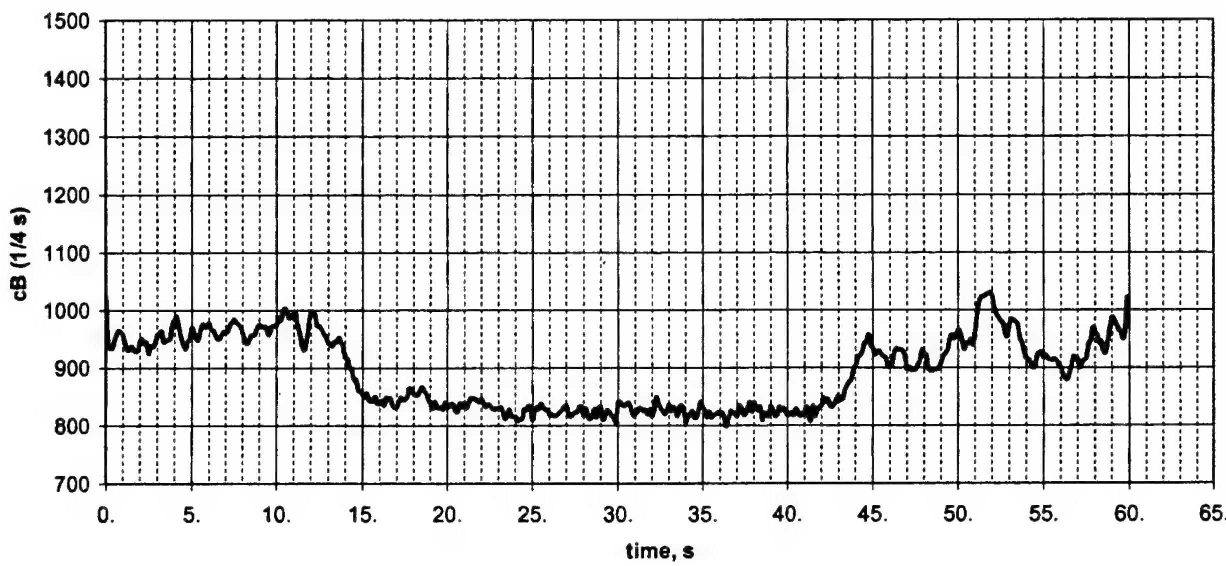

Figure A-6. Spectral Energy: Segment F (19:15 – 20:15)

Voiding and Grooming

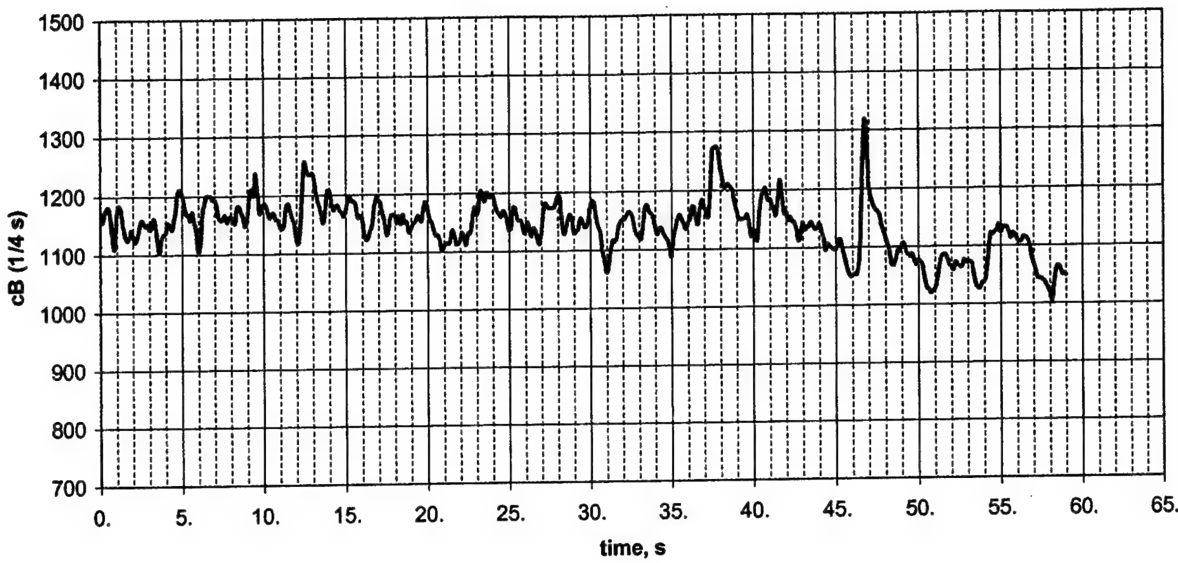

Figure A-7. Spectral Energy: Segment G (82:20 – 83:20)
Jumping, Running, and Frantic

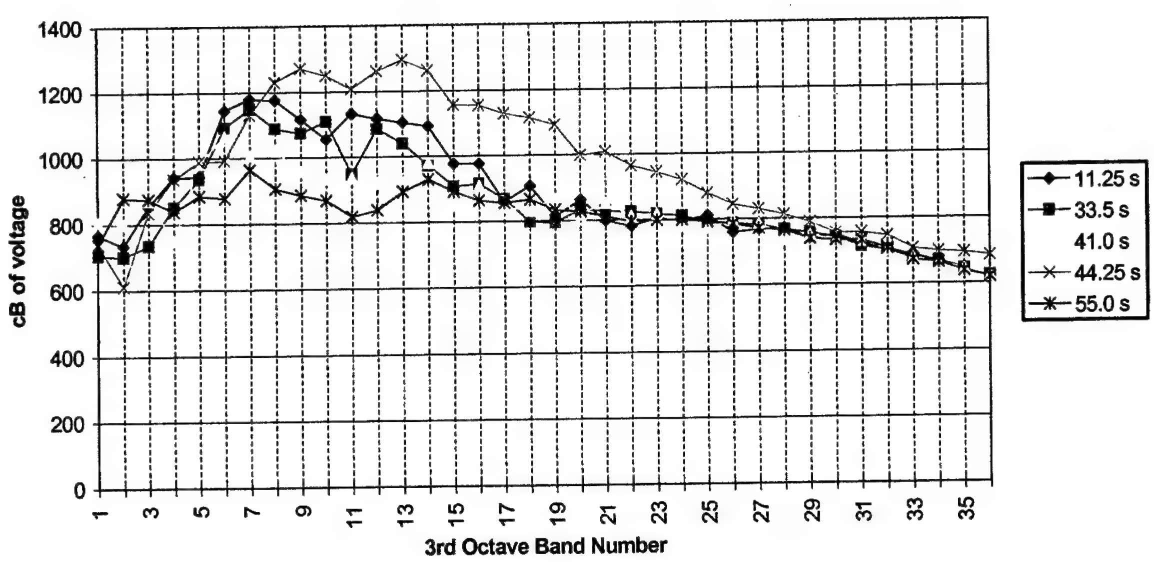

Figure A-8. Deer Headshake Acceleration Spectra (Segment B)
3rd Octave Spectra (1.3-4k Hz)

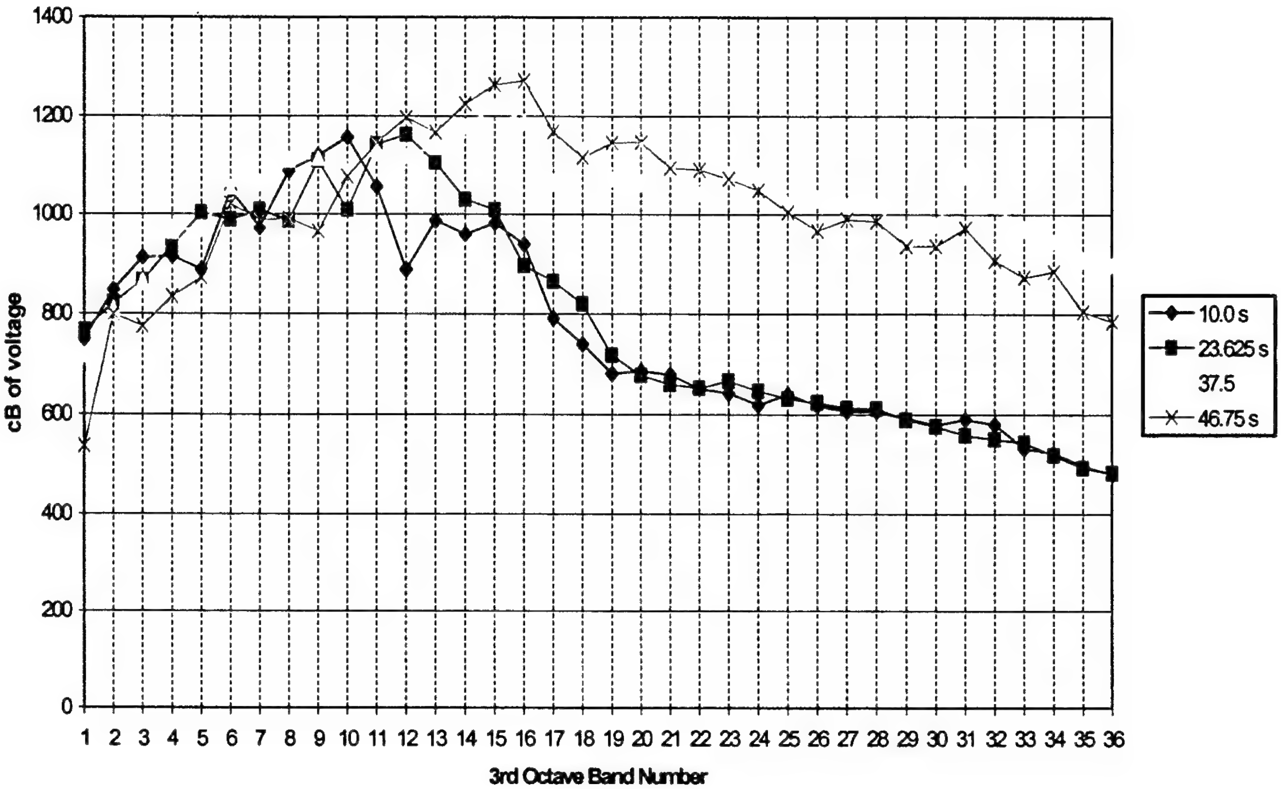

Figure A-9. Deer Frantic Acceleration Spectra (Segment G)

3rd Octave Spectra: 1.3 to 4k Hz

Appendix B: Velocity and Acceleration time histories

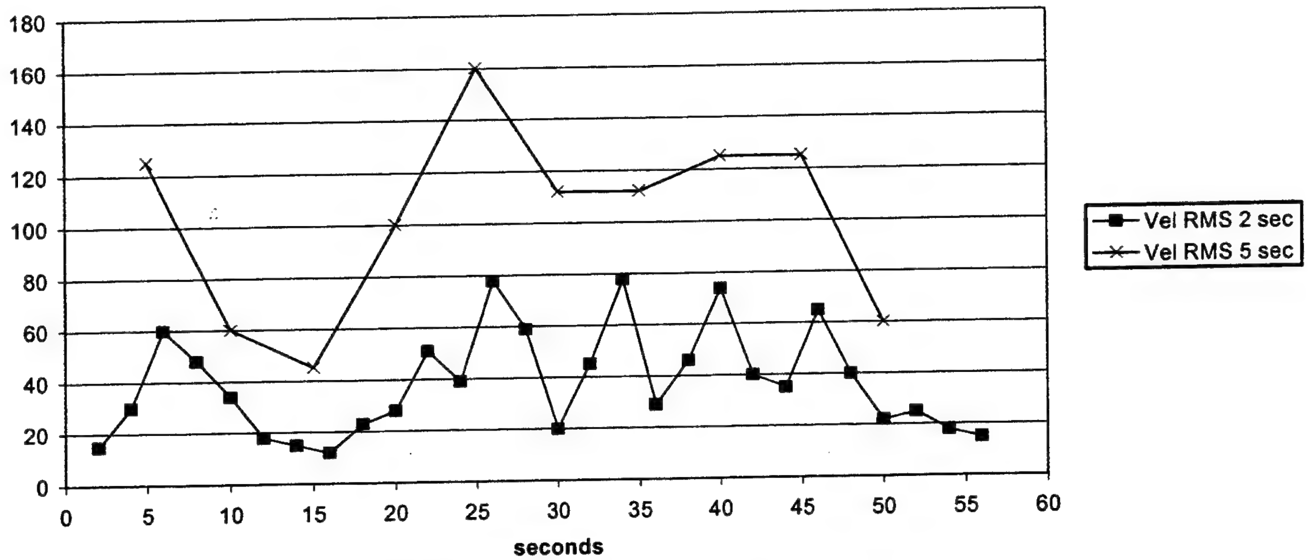

Figure B-1. RMS Velocity: Segment A (2:25 – 3:25)

Walking and Trotting

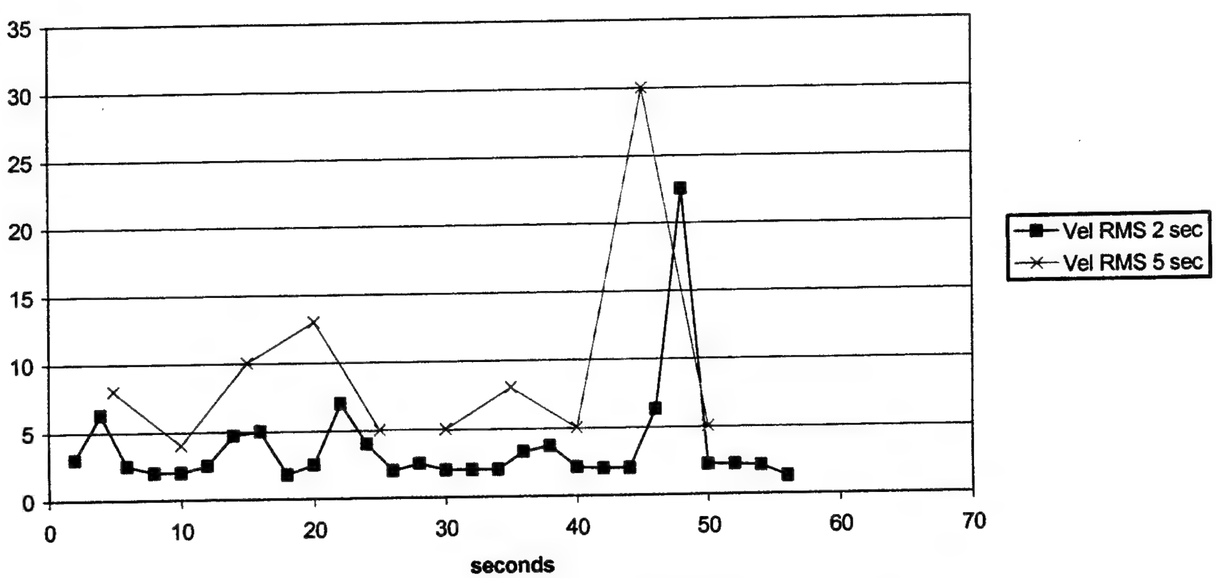

Figure B-2. RMS Velocity: Segment B (4:19 – 5:19)

Walking and Headshake

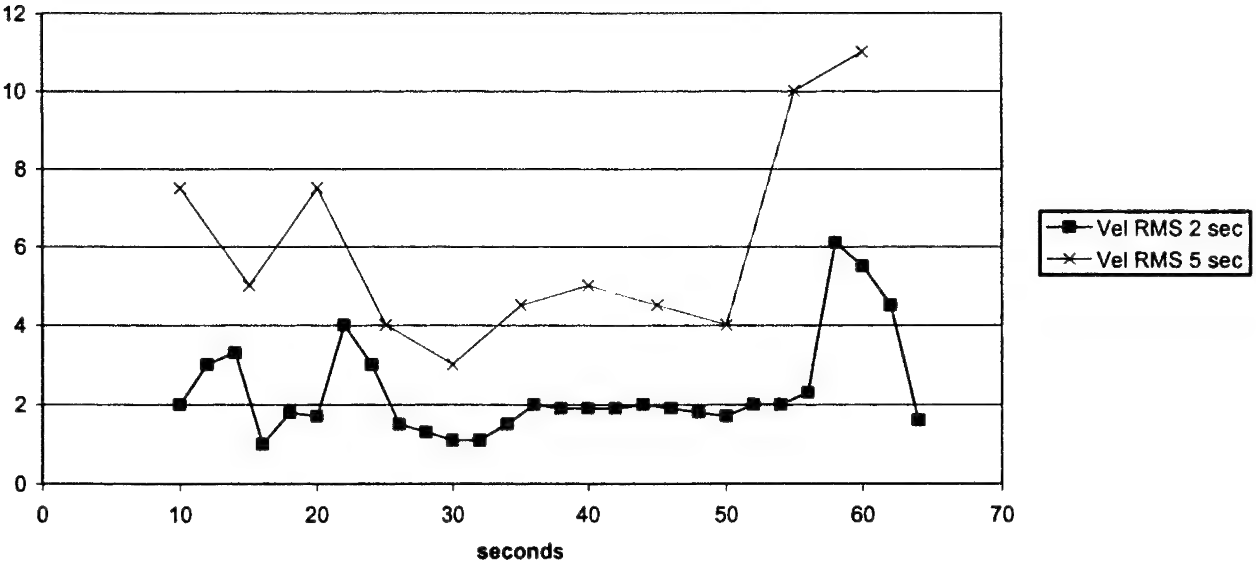

Figure B-3. RMS Velocity: Segment C (5:19 – 6:19)

Headshake

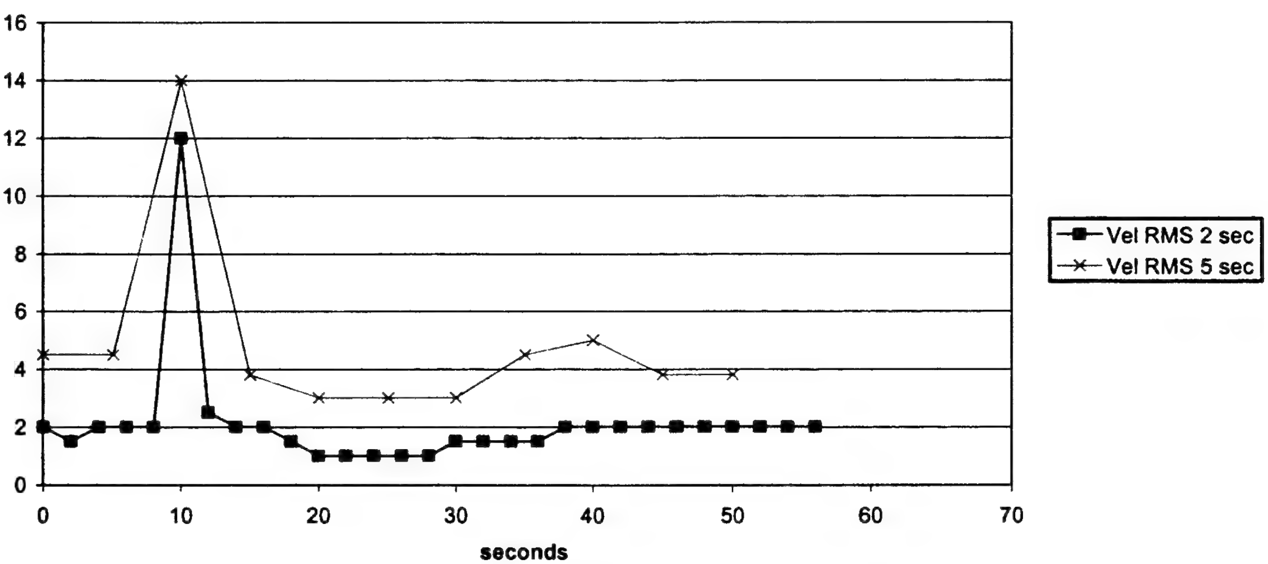

Figure B-4. RMS Velocity: Segment D (7:17 – 8:17)

Headshake and Standing

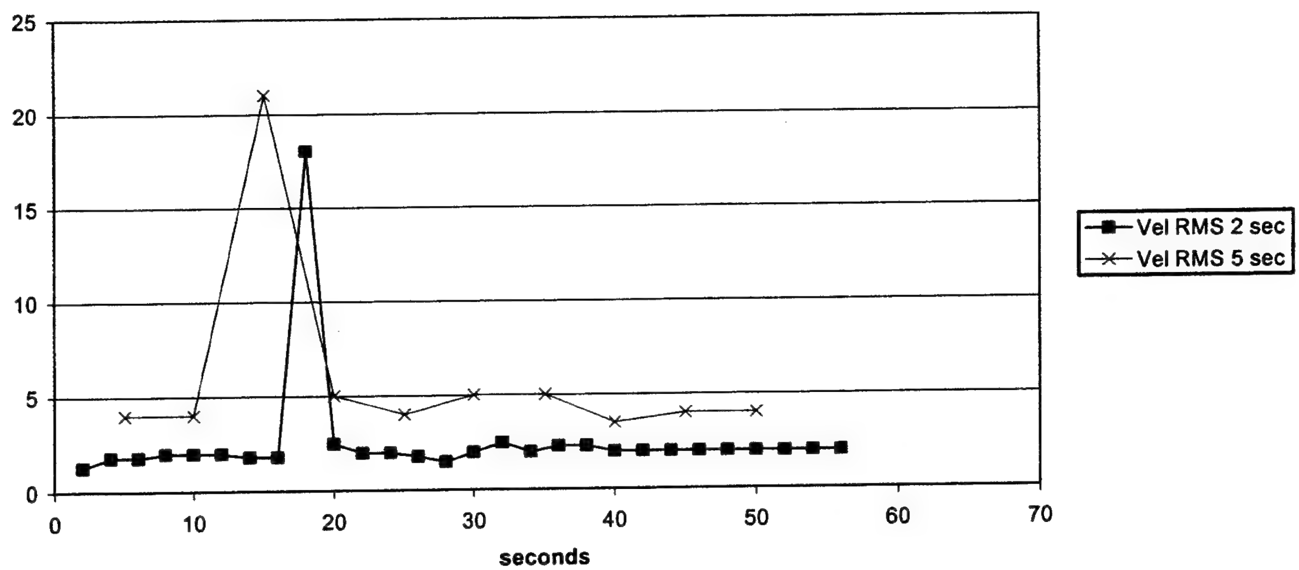

Figure B-5. RMS Velocity: Segment E (8:30 – 9:30)

Headshake and Standing

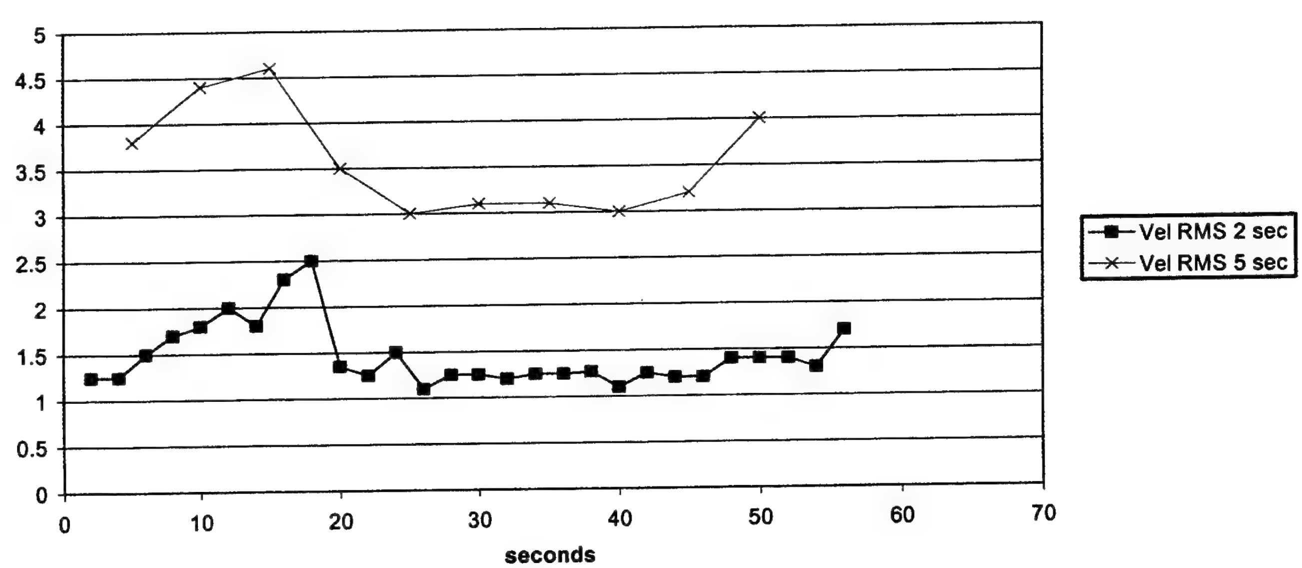

Figure B-6. RMS Velocity: Segment F (19:15 – 20:15)

Voiding and Grooming

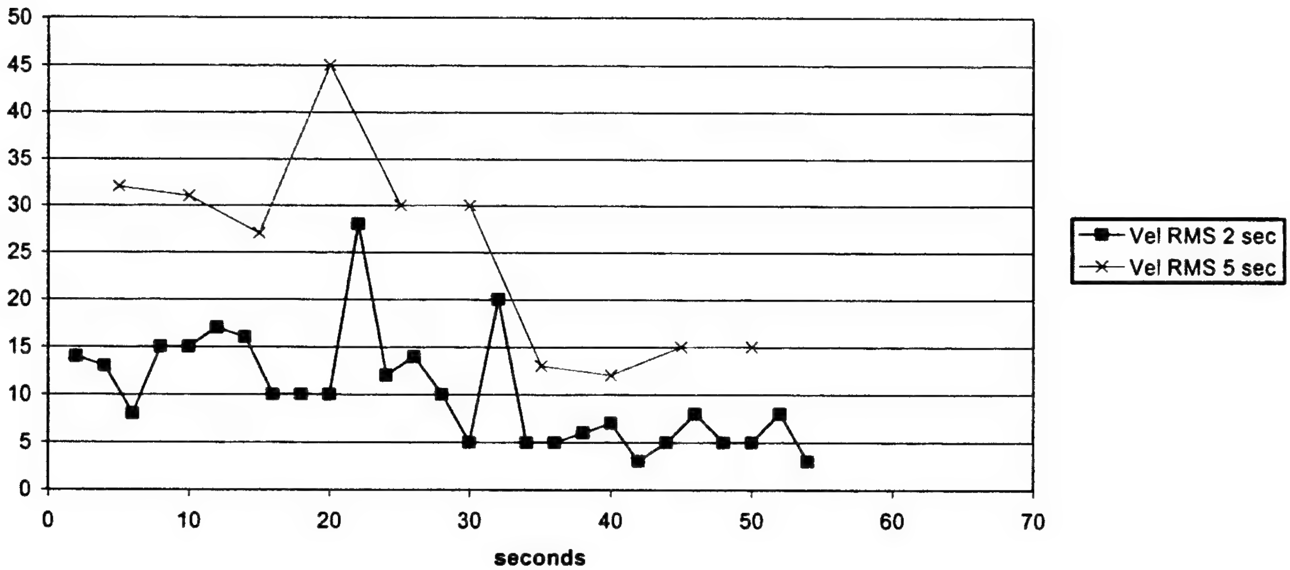

Figure B-7. RMS Velocity: Segment F (82:15 – 83:15)

Jumping, Running, and Frantic

Appendix C: Maximum RMS Accelerations with 1-, 2-, and 5-second intervals

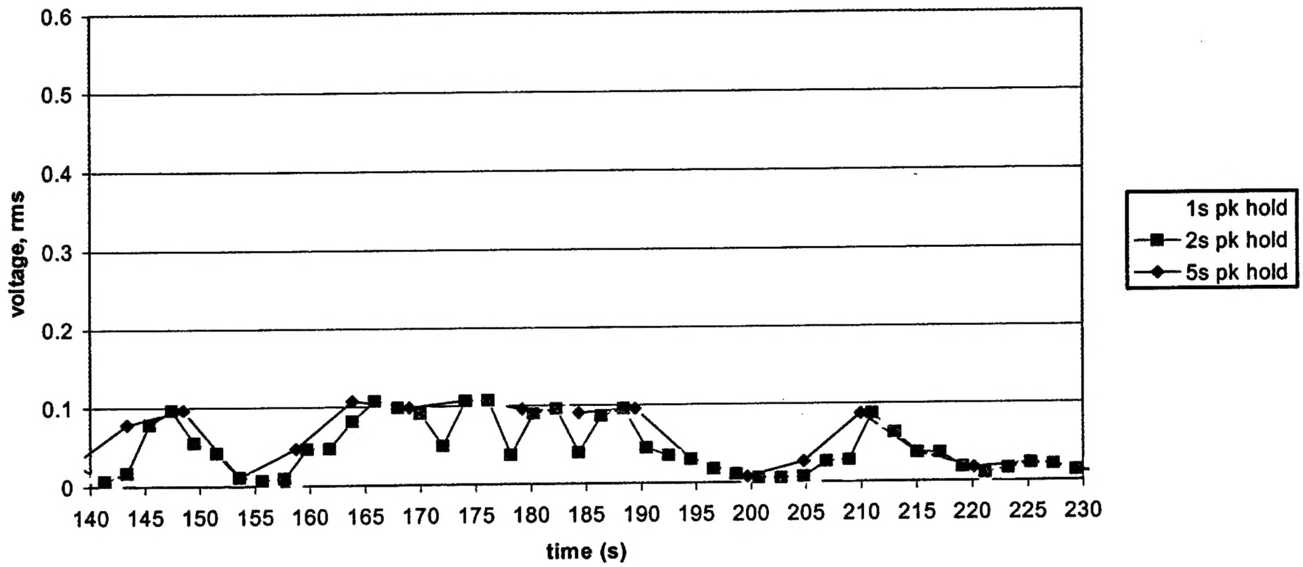

**Figure C-1. Maximum RMS Acceleration: Segment A (2:25 – 3:25)
Walking and Trotting**

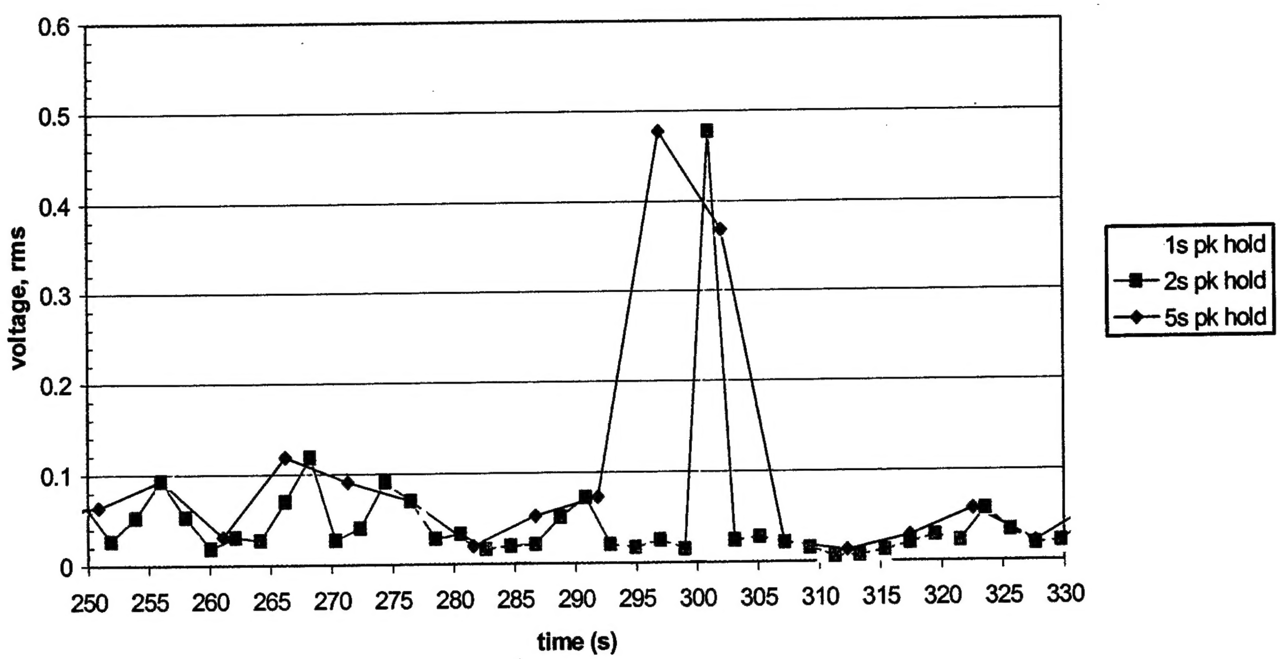

Figure C-2. Maximum RMS Acceleration: Segment B (4:19 – 5:19)

Walking and Headshake

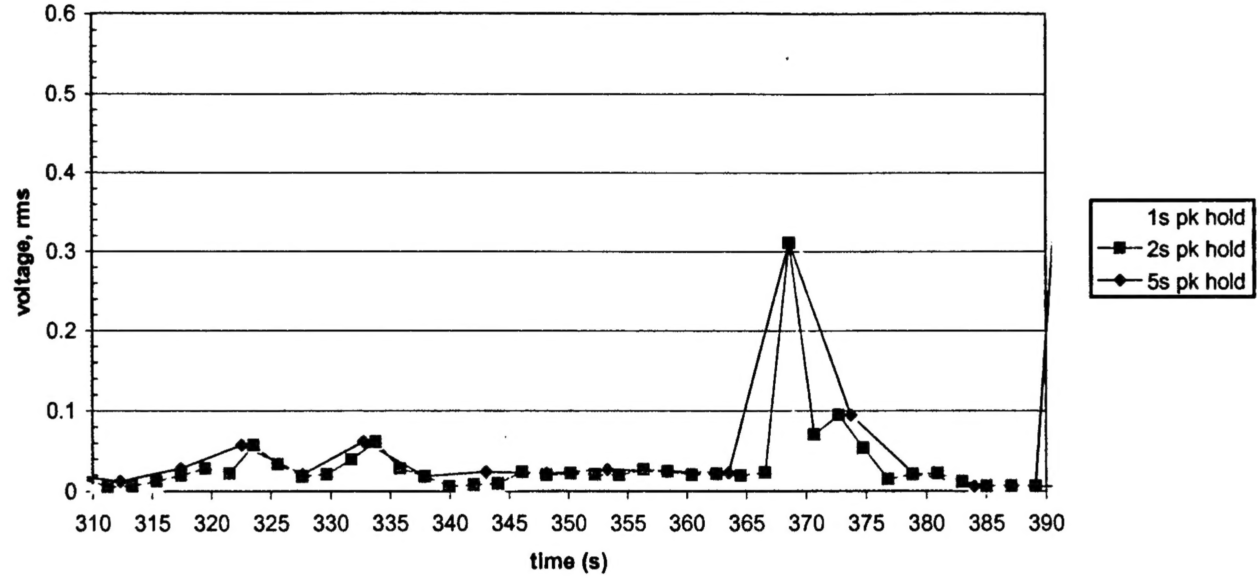

Figure C-3. Maximum RMS Acceleration: Segment C (5:19 – 6:19)

Headshake

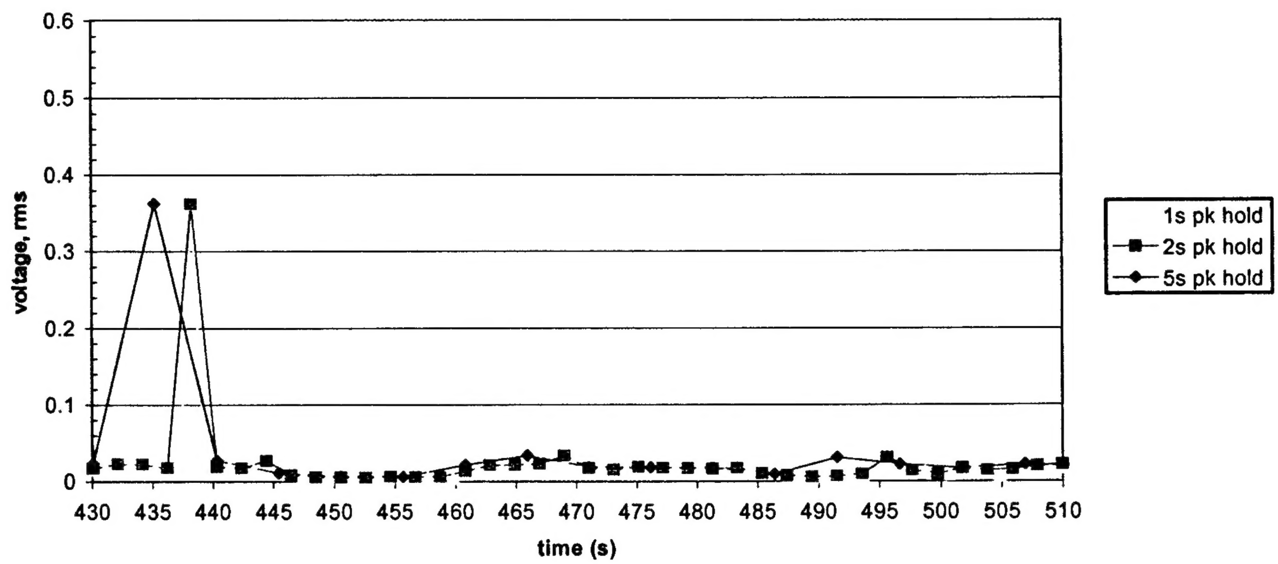

Figure C-4. Maximum RMS Acceleration: Segment D (7:17 – 8:17)

Headshake and Standing

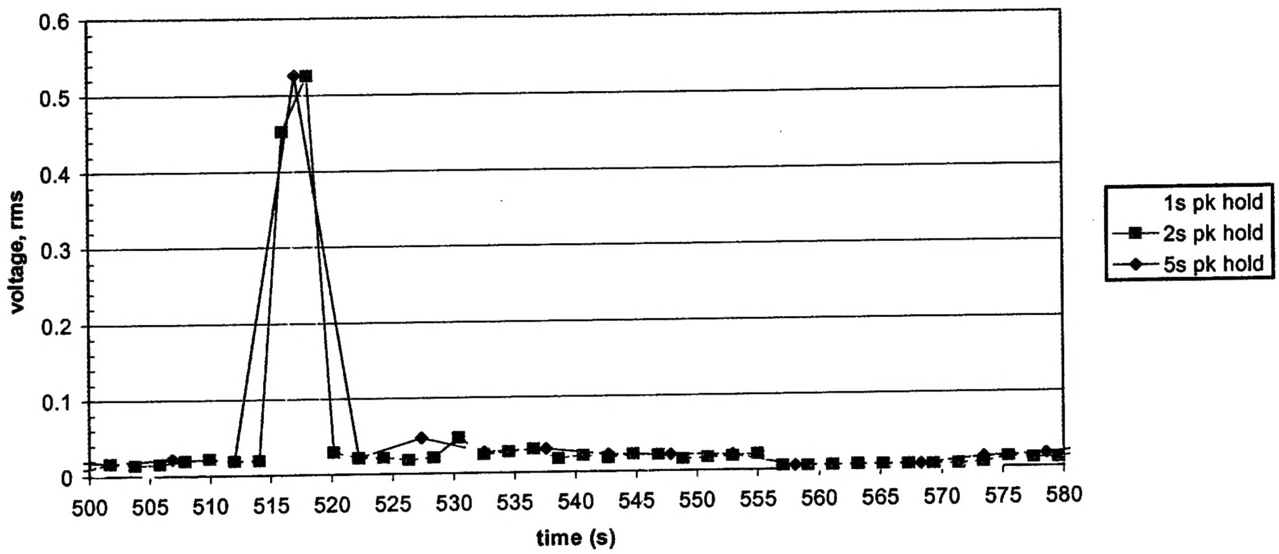

Figure C-5. Maximum RMS Acceleration: Segment E (8:30 – 9:30)

Headshake and Standing

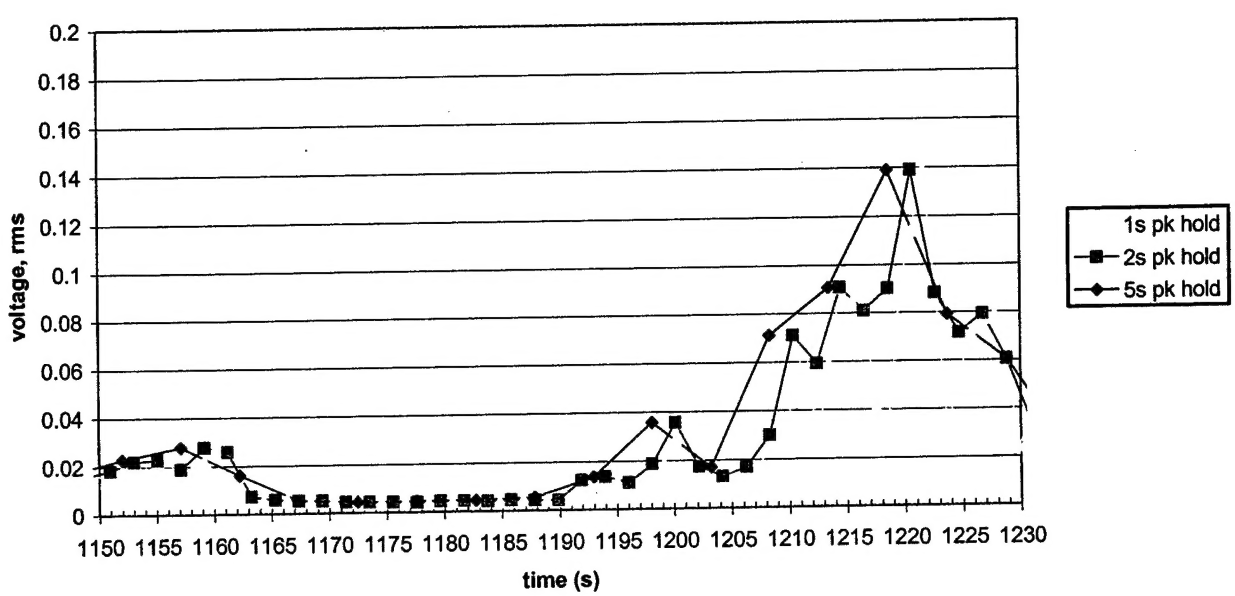

Figure C-6. Maximum RMS Acceleration: Segment F (19:15 – 20:15)

Voiding and Grooming

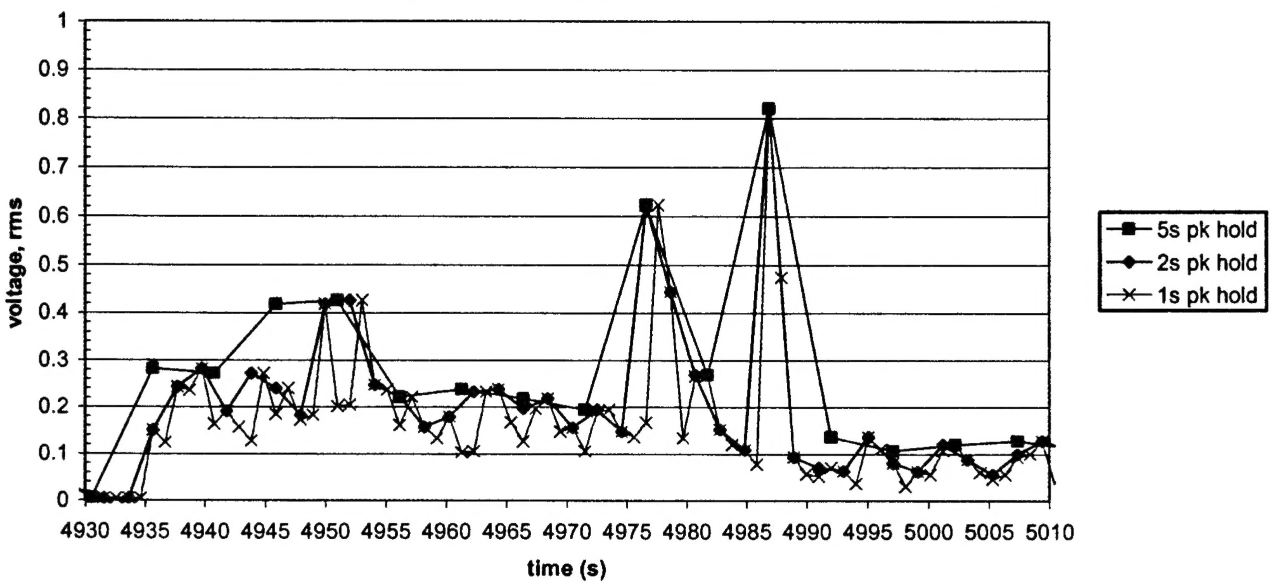

Figure C-7. Maximum RMS Acceleration: Segment G (82:15 – 83:15)

Jumping, Running, and Frantic